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NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION
PATUXENT RIVER, MARYLAND 20670-5304



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SUBSTITUTES FOR OZONE DEPLETING AEROSOL ELECTRICAL CONTACT CLEANERS AND CLEANER/LUBRICANTS

by

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24 January 1996

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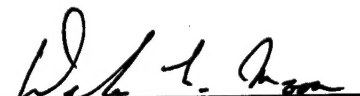
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ABSTRACT

With the production of Class I Ozone Depleting Substances discontinued as of January 1996, it became necessary to identify suitable replacements for chlorofluorocarbon (CFC-113) and trichloroethane (TCA) based electrical contact cleaners and cleaner/lubricant products. These products were available under military specifications MIL-C-81964 and MIL-C-83360. Two hydrochlorofluorocarbon (HCFC-141b) blends were identified as substitutes and recommended for interim use.

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INTRODUCTION

Class I Ozone Depleting Substances (ODS's), including trichlorotrifluoroethane (CFC-113), 1,1,1-trichloroethane (TCA), and dichlorodifluoromethane (CFC-12), will no longer be produced as of January 1996. These materials are components of several aerosol electrical maintenance products used commonly throughout the U.S. Navy: MIL-C-83360, Type III and MIL-C-81964 aerosol electrical contact cleaners, and MIL-C-83360, Types I, II, and IV contact cleaner/lubricant products. This study was conducted to identify suitable replacements for these products.

Currently, most of the non-CFC products commercially available for electrical contact cleaning fall into one of two categories. Hydrocarbon based materials generally exhibit excellent cleaning properties, materials compatibility, and environmental compatibility, but have the draw-back of flammability. Hydrochlorofluorocarbon (HCFC-141b) based materials exhibit excellent cleaning properties and minimal flammability, but often have materials compatibility problems and are classified as Class II ODS's. Class II ODS's have a lower Ozone Depleting Potential (ODP) than Class I and are still permitted for use in applications such as aircraft maintenance where no other suitable alternatives exist. Environmental data are provided in table 1 for cleaning solvents and aerosol propellants relevant to this study.

Table 1
ENVIRONMENTAL DATA

Solvent	ODP	GWP ⁽¹⁾
CFC-113	0.80	2800
1,1,1-TCA	0.15	45
HCFC-141b	0.10	1500
Perfluorocarbons (PFC's)	0.00	>10000
CFC-12	1.00	6200
CFC-134a	0.00	500
CO ₂	0.00	1

NOTE: (1) Global Warming Potential (GWP).

Flammable products are undesirable for Navy applications due to safety concerns; contact with energized equipment could cause ignition of the material. Because of this, HCFC-141b based products were chosen for evaluation. Testing of pure HCFC-141b on polycarbonate plastic, a common material used in avionics components, clearly indicated a materials compatibility problem. For this reason, combinations of HCFC-141b with less aggressive solvents were explored. These types of products would hopefully combine the excellent cleaning capability and low flammability of HCFC-141b with the materials compatibility of a milder solvent. Products containing HCFC-141b blended with PFC's or ethanol (EtOH) were particularly attractive, due to their low toxicity and better compatibility with plastics, although there is concern over the high GWP of PFC's. Alcohol blends are also desirable due to the capability of alcohols to remove polar soils, such as salt residues that may be present as a result of the typical

Navy operating environment. Blends with methanol (MeOH) are common but are less desirable due to increased toxicity and inclusion of MeOH on the 1990 Clean Air Act Hazardous Air Pollutants (HAP's) list.

Since a standard test method for cleaning effectiveness of aerosol contact cleaners was not available, it was necessary to develop a suitable method. The test decided upon was a simple gravimetric analysis using aluminum panels soiled with common Navy operational fluids; hydraulic fluid, corrosion preventive compound, silicone oil, and rosin flux. This test was a reasonable simulation of the intended application of the material and was simple enough to expedite testing.

To test compatibility with plastics, ASTM F484, Stress-crazing of Acrylic Plastics in Contact with Liquid or Semiliquid Materials, was used. Testing was performed on acrylic and polycarbonate plastics. These materials are expected to be encountered in normal use and also are known to be susceptible to solvent attack. Similarly, four common elastomeric materials and four circuitboard conformal coating materials were identified that would likely be encountered in normal use. These materials were subject to repeated exposure of the test materials from the aerosol container to simulate expected service conditions.

Testing in all cases was performed for pure solvent cleaning materials only, without the inclusion of lubricant in the formulation. This was done to avoid the difficulty of removing the residual lubricant and thus introducing error into the test. Results obtained with cleaners should apply to cleaner/lubricant materials, assuming compatibility of the lubricant with the solvent system. This could not be verified with commercially available materials packaged in metal cans; however, HCFC-141b/Ethanol/Silicone lubricant formulations prepared in-house were packaged in glass aerosol bottles and verified to be homogenous.

MATERIALS

Materials evaluated in this study are given in table 2. CFC-113 and 1,1,1-TCA were used as the control solvents (shown in boldface) since these are currently used in contact cleaner and cleaner/lubricant products.

Table 2
MATERIALS

Material	Supplier	Composition ⁽¹⁾
CFC-113	NAWCAD Patuxent River	100% CFC-113, Hydrofluorocarbon (HFC-134a) Propellant
1,1,1-TCA	NAWCAD Patuxent River	100% 1,1,1-TCA, HFC-134a Propellant
Envi-ro-tech 1677	Tech Spray	90% HCFC-141b, 10% EtOH, CO ₂ Propellant
Envi-ro-tech 2410	Tech Spray	88% HCFC-141b, 10% EtOH, 2% Lubricant Blend, CO ₂ Propellant
ES 1681	Chemtronics	50% HCFC-141b, 50% PFC's, CO ₂ Propellant
ES 883	Chemtronics	45-50% HCFC-141b, 45-50% PFC's, 1-10% Synthetic Oil Lubricant, CO ₂ Propellant
Contact Re-Nu	Miller Stephenson	96% HCFC-141b, 4% MeOH, CO ₂ Propellant
Ecolink 2005	Ecolink	100% HCFC-141b, CO ₂ Propellant
141b/EtOH	NAWCAD Patuxent River	88% HCFC-141b, 12% EtOH, HCFC-134a Propellant

NOTE: (1) Composition given as weight percent of bulk material or usable product.

EXPERIMENTAL PROCEDURES

CLEANING CAPABILITY

Twelve 2 x 5 in. aluminum panels conforming to QQ-A-250/13 were each weighed and then soiled with five drops of one of the following four materials: MIL-C-81309 (corrosion preventive compound), MIL-H-83282 (hydraulic fluid), VV-D-1078 (silicone damping fluid), and MIL-F-14256, Type R (rosin soldering flux). Three panels were prepared with each of the four soil types. MIL-C-81309 soil was cured at 150°F for 1 hr followed by a 15 min air cool, and all other soils were allowed to air dry for 1 hr. Soiled weights were recorded. The approximate soil weights were as follows: MIL-C-81309 - 15 mg, MIL-H-83282 - 70 mg, VV-D-1078 - 35 mg, and MIL-F-14256 - 10 mg. Panels were placed at a 45 deg angle, and the test material was sprayed approximately 3 in. from the panel surface for 5 sec. Test fluid was allowed to drip off the panel and/or evaporate to a constant weight. The back of the panel and bottom edge were blotted to remove displaced soil. Final weight was recorded and percent cleaning efficiency was determined. Calculations were performed as follows:

$$CE = \frac{w_s - w_f}{w_s - w_i} \times 100$$

Where: CE = Cleaning efficiency, %

w_s = Soiled weight

w_f = Final weight

w_i = Initial Weight

EFFECTS ON PLASTICS

Products were tested according to ASTM F 484 for their effect on polycarbonate (MIL-P-83310), Type A acrylic (MIL-P-5425, Finish A), and Type C acrylic (MIL-P-25690). Flannel swatches on the stress point were saturated with the test material from the aerosol container every 30 min for 8 hr on acrylic specimens and every 15 min for 2 hr on polycarbonate specimens.

EFFECTS ON ELASTOMERS

Four common elastomeric materials were tested: butadiene-nitrile, butadiene-styrene, butyl rubber, and EPDM. Ten applications were applied in 30-min intervals, with each application consisting of two short bursts (~0.5 sec) of the test material from the aerosol container on each side of the sample. Drying time after the final application was 1 hr. The change in hardness was determined with a Shore A durometer for both exposure methods.

EFFECTS ON CONFORMAL COATINGS

Acrylic, epoxy, silicone, and urethane resin conformal coatings conforming to MIL-I-46058 (Types AR, SR, ER, and UR, respectively) were applied to 1 x 2 x 1/8 in. aluminum panels with a Fisher-Payne dip-coater. Initially, test panels were subjected to 1 hr of immersion in the solvent material. The control solvents completely dissolved the Type AR coating with this type of exposure. The method was therefore changed to decrease the severity of the exposure. Ten applications were applied in 30-min intervals, with each application consisting of two short bursts (~0.5 sec) of the test material on each side of the sample. Drying time after the final application was 1 hr. The weight change of the coating was determined. Initial coating thicknesses were approximately as follows: AR - 1.5 mils, ER - 2.0 mils, SR - 4.5 mils, and UR - 2.0 mils. The results presented are from the aerosol exposure method.

FLAME EXTENSION

The products were tested in accordance with ASTM D3065. Each product was sprayed across a bunsen burner, and an estimation of the resulting flame length was made.

RESULTS

Cleaning efficiency data provided in table 3 indicate that Chemtronics ES 1681 was more effective than CFC-113 and about as effective as TCA in the removal of oily soils (MIL-H-83282 and VV-D-1078). Both Envi-ro-tech 1677 and the in-house mixture of HCFC-141b/EtOH were more effective in removing all four soils than was CFC-113. Some variation is evident in the data due to the inherent difficulty of obtaining constancy in a manual test method. Even with a relatively conservative estimation of the error, however, the results are suitable to draw reasonable conclusions about solvent performance relative to the control solvents.

Table 3
PERCENT CLEANING EFFICIENCY⁽¹⁾ ON VARIOUS SOILS

Material	MIL-C-81309	MIL-H-83282	VV-D-1078	MIL-F-14256 ⁽²⁾
CFC-113	30 ± 8	63 ± 15	32 ± 5	24 ± 7
1,1,1-TCA	94 ± 2	98 ± 1	95 ± 2	94 ± 4
Envi-ro-tech 1677	76 ± 24	99 ± 1	97 ± 4	100 ± 2
HCFC-141b/EtOH ⁽³⁾	48 ± 10	91 ± 3	56 ± 11	83 ± 3
ES 1681	8 ± 6	97 ± 2	93 ± 7	16 ± 8

NOTES: (1) 90% Confidence Limits; t-distribution.
 (2) Type R.
 (3) In-house; 88/12 blend; HFC-134a propellant.

Results of compatibility testing of solvents on acrylic and polycarbonate are provided in table 4. Various in-house mixtures of HCFC-141b and EtOH were formulated and tested to determine if varying percentages of EtOH would improve compatibility with plastics. The data indicate that Chemtronics ES 1681 and HCFC-141b/EtOH mixtures containing at least 10% EtOH, such as Envi-ro-tech 1677, are compatible with polycarbonate under the exposure conditions of this test method. Although TCA is one of the solvents currently used for contact cleaning, not surprisingly, it is shown to be aggressive towards polycarbonate and Type A acrylic. All potential substitutes shown in table 4 had some effect on acrylic, with Chemtronics ES 1681 showing the mildest effect.

Table 4
EFFECTS ON PLASTICS

Material	Acrylic - Type A	Acrylic - Type C	Polycarbonate
CFC-113	8 hr - No Effect	8 hr - No Effect	2 hr - No Effect
1,1,1-TCA	1.25 hr - Break	8 hr - No Effect	0.5 hr - Break
ES 1681	8 hr - Mod Craze	8 hr - No Effect	2 hr - No Effect
141b/EtOH (88/12)	8 hr - Sev Craze	8 hr - Slt Craze	2 hr - No Effect
Envi-ro-tech 1677	8 hr - Sev Craze	8 hr - No Effect	2 hr - No Effect
141b/EtOH (92/8)	8 hr - Sev Craze	8 hr - Slt Craze	1.13 hr - Break
141b/EtOH (94/6)	8 hr - Sev Craze	8 hr - Slt Craze	0.13 hr - Break
Contact Re-Nu	NT	NT	0.02 hr - Break
Ecolink 2005	NT	NT	0.02 hr - Break

*NT - Not Tested.

Results of the aerosol exposure test on elastomeric materials are provided in table 5. In most cases, the effects on elastomers were generally too small to be accurately measured. The HCFC-141b/EtOH blend and Envi-ro-tech 1677 did cause a slight decrease in hardness of butadiene-nitrile and butadiene-styrene.

Table 5
PERCENT DUROMETER HARDNESS CHANGE⁽¹⁾ OF ELASTOMERS

Material	Butadiene-Nitrile	Butadiene-Styrene	Butyl Rubber	EPDM
CFC-113	+0.6 ± 3.4	+1.6 ± 4.0	+0.2 ± 1.7	+1.2 ± 5.9
1,1,1-TCA	+1.4 ± 2.5	-4.2 ± 7.9	-1.5 ± 3.9	0.0 ± 1.0
ES 1681	-0.8 ± 1.5	-1.6 ± 3.6	+1.2 ± 3.3	-1.2 ± 1.4
141b/EtOH ⁽²⁾	-4.0 ± 1.7	-3.6 ± 1.8	-1.4 ± 2.2	-2.2 ± 4.6
Envi-ro-tech 1677	-3.5 ± 2.1	-3.9 ± 2.4	-1.8 ± 2.5	-2.0 ± 3.1
HCFC-141b	-0.8 ± 2.7	-0.6 ± 4.8	-1.7 ± 0.8	+1.2 ± 4.2

NOTES: (1) 90% Confidence Limits; t-distribution.
(2) In-house; 88/12 blend.

Results of the aerosol exposure test on conformal coatings are provided in table 6. Changes were generally quite small and do not appear to be significant.

Table 6
PERCENT WEIGHT CHANGE⁽¹⁾ OF CONFORMAL COATINGS⁽²⁾

Material	AR	ER	SR	UR
CFC-113	+0.4 ± 0.4	+0.4 ± 0.3	-0.7 ± 0.1	-0.1 ± 0.1
1,1,1-TCA	+1.9 ± 0.2	+0.2 ± 0.1	-0.5 ± 0.2	-0.2 ± 0.2
ES 1681	+0.4 ± 0.3	0.0 ± 0.1	-0.4 ± 0.2	+0.2 ± 0.1
141b/EtOH ⁽³⁾	-0.4 ± 0.7	+0.2 ± 0.5	-0.9 ± 0.0	0.0 ± 0.1
Envirotech 1677	+0.2 ± 0.4	+0.1 ± 0.1	-0.5 ± 0.2	0.0 ± 0.1
Ecolink 2005	+1.5 ± 1.3	-0.1 ± 0.4	-1.2 ± 0.4	+1.5 ± 0.0

NOTES: (1) 10% Confidence Limits; t-distribution.
(2) Conforming to MIL-I-46058.
(3) In-house.

Results of the ASTM D 3065 flame extension test are given in table 7. Some variation in flame length was noticed for Envi-ro-tech 1677.

Table 7
FLAME EXTENSION

Material	Flame Extension (in.)
CFC-113	0
1,1,1-TCA	1
Chemtronics ES 1681 ⁽¹⁾	1
Chemtronics ES 883 ⁽¹⁾⁽²⁾	1
Envi-ro-tech 1677 ⁽³⁾	4-12
HCFC-141b	4
141b/EtOH (88/12)	6
Envi-ro-tech 2410 ⁽²⁾⁽⁴⁾	24

- NOTES: (1) Chemtronics; HCFC-141b/PFC (50/50).
 (2) 1-10% synthetic oil lubricant added.
 (3) Tech Spray; HCFC-141b/EtOH (90/10).
 (4) 2% silicone lubricant added.

DISCUSSION

The Chemtronics ES 1681 [HCFC-141b/PFC (50/50)] was more effective at removal of the oily soils, MIL-H-83282 and VV-D-1078, than CFC-113, and about as effective as TCA. This was attributed to displacement of the soil resulting from the higher pressure obtained with the carbon dioxide propellant. This solvent system was not very effective, however, in the removal of the semisolid soils, MIL-C-81309 and MIL-F-14256.

The HCFC-141b/EtOH (88/12) in-house blend and Envi-ro-tech 1677 were more effective than CFC-113 in removing all four soils, but not as effective as 1,1,1-TCA.

Compatibility with plastics was a problem for pure HCFC-141b and for formulations with a high percentage of HCFC-141b. The HCFC-141b/EtOH blends appear to be compatible with polycarbonate under the short-term exposure conditions experienced in this evaluation when no more than 90% HCFC-141b is included in the formulation. The polycarbonate test was used as a selection criteria for recommending products, since it is one of the more sensitive materials likely to be encountered in field applications. Chemtronics ES 1681 was noticeably less aggressive towards acrylic test specimens than any of the EtOH blends due to a high percentage of perfluorocarbons in the formulation.

Problems in the flame extension test were noticed with Envi-ro-tech 1677 and 2410. Some sporadic variation in flame length occurred with Envi-ro-tech 1677, possibly due to incomplete mixing of the solvents when packaged with carbon dioxide. Also, an unusually high flame extension was observed for Envi-ro-tech 2410, which is identical to Envirotech 1677 except for

the addition of a lubricant. Since the addition of a nonvolatile lubricant would not be expected to significantly change the flammability of the material, the lubricant probably increased the miscibility problem of the product. This may have caused further separation of EtOH from the mixture to the extent that the measured flame extension was of pure EtOH.

CONCLUSIONS

Chemtronics ES 1681 contact cleaner [HCFC-141b/PFC (50/50); CO₂ propellant] is as effective as CFC-113 in the removal of light, oily soils, such as MIL-H-83282 hydraulic fluid and VV-D-1078 silicone oil. Chemtronics ES 1681 should not significantly affect plastics, elastomers, and conformal coatings under conditions of limited exposure.

Envi-ro-tech 1677 [HCFC-141b/EtOH (90/10); CO₂ propellant] and the HCFC-141b/EtOH (88/12; HFC-134a propellant) in-house formulation are more effective than CFC-113 in cleaning four types of test soils expected to be encountered in normal field use. Some significant crazing effects were seen in stressed MIL-P-5425 Finish A and MIL-P-25690 acrylics; therefore, caution should be exercised if a high degree of plastics compatibility is critical.

RECOMMENDATIONS

Chemtronics ES 1681 is recommended for light cleaning of electrical contacts, such as removing light oils and particulates, where compatibility with plastics is desired.

Chemtronics ES 883 is recommended for light cleaning and lubrication of electrical contacts, where compatibility with plastics is desired. This product is based on the solvent blend found in ES 1681, with the addition of synthetic oil lubricant, and is therefore expected to exhibit similar cleaning performance and material compatibility.

Envi-ro-tech 1677 is recommended where a more aggressive solvent is desired for the cleaning of electrical contacts. A similar solvent system with a nonflammable propellant other than carbon dioxide, such as HFC-134a, would be preferred. Caution should be exercised when used on or around plastic components.

HCFC-141b/EtOH blend (88-90% HCFC-141b) with 1-2% silicone oil (100-500 cs) and HFC-134a propellant is recommended where a more aggressive solvent is desired for the cleaning and lubrication of electrical contacts. Caution should be exercised when used on or around plastic components.

Note: The performance criteria for these recommended contact cleaner and cleaner/lubricant products have been drafted in a proposed military specification.

FUTURE WORK

Due to the phaseout of HCFC's, the use of products recommended in this report may be a short-term solution. Also, environmental regulations may limit the use of PFC's for aerosol applications. New products suitable for this application should be evaluated as they become available.

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